(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 255 305 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 87306575.9

(51) Int. Cl.⁴: G11B 7/13

(22) Date of filing: 24.07.87

(30) Priority: 28.07.86 JP 178513/86
31.03.87 JP 79241/87
23.01.87 JP 13611/87

(43) Date of publication of application:
03.02.88 Bulletin 88/05

(84) Designated Contracting States:
FR GB NL

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(54) Focusing error detector and optical data detecting device incorporating the focusing error detector.

(57) A focusing error detector comprises a light source, a collimator lens for making parallel the pencil of rays emitted by the light source, an objective lens which focuses the parallel pencil of rays to form a beam spot on a data-recording disc with data tracks and guide tracks formed thereon and which receives the pencil of rays reflected from the data-recording disc, an optical system for forming a beam spot from the reflected pencil of rays incident to the objective lens, and an optical detector having a plurality of divided optical sensor blocks for receiving the formed beam spot so as to detect the focusing error of the beam spot formed on the data-recording disc on the basis of the configuration of the received beam spot.

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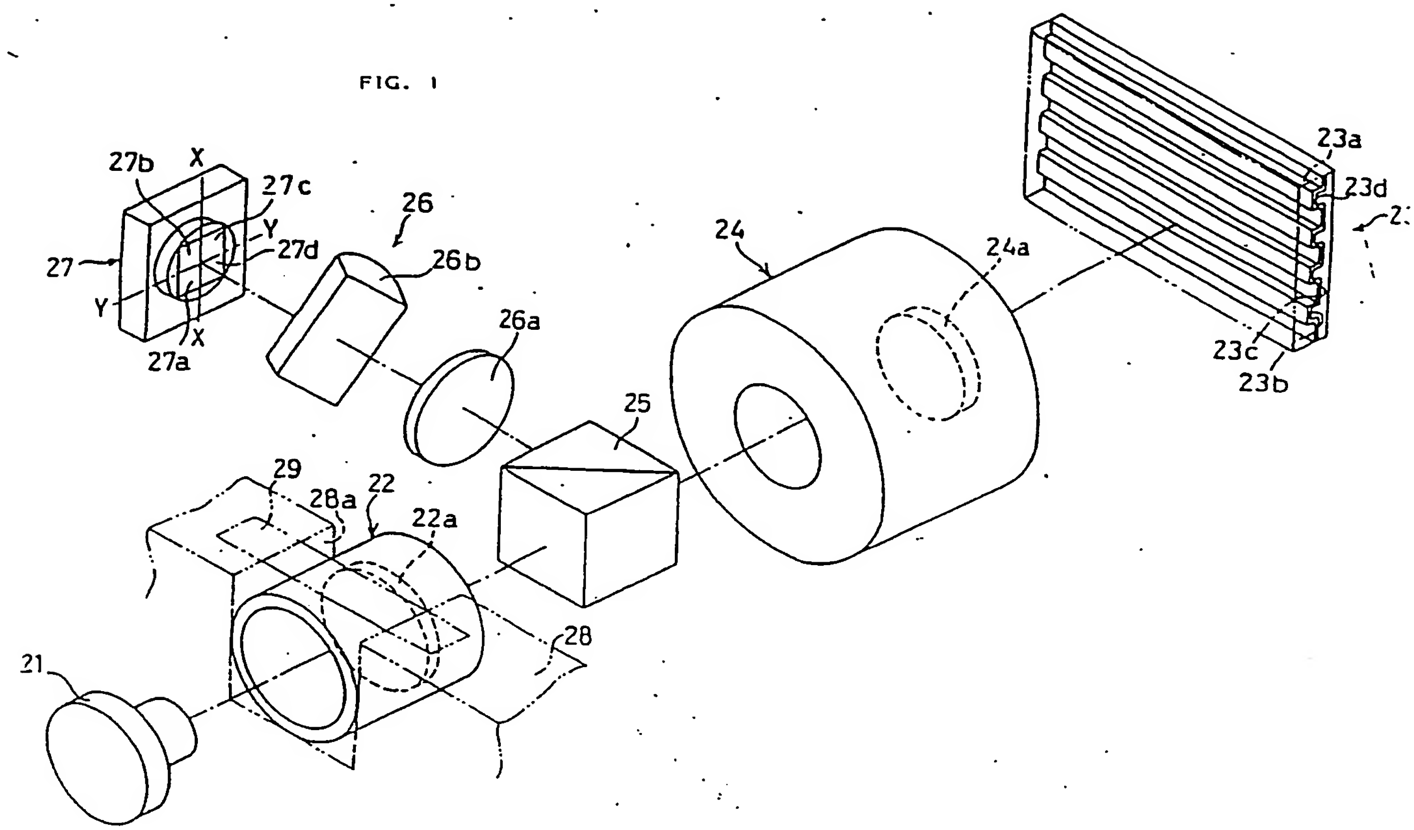
FIG. 1


27b
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27c
Y
27d
27
Y
X
27a
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24a
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23d
23c
23b
25
29
28a
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22a
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FOCUSING ERROR DETECTOR AND OPTICAL DATA DETECTING DEVICE INCORPORATING THE FOCUSING ERROR DETECTOR

BACKGROUND OF THE INVENTION

The present invention relates to a focusing error detector for use in an optical data detecting device which records or reproduces data on a data-recording disc such as an optical disc or an optical magnetic disc with concentric or spiral data tracks and guide tracks formed thereon.

The conventional focusing error detector typically comprises, as shown in Fig. 5, a semiconductor laser 1 as a light source, a collimator lens 2 for making parallel the pencil of rays emitted by the semiconductor laser 1, an objective lens 4 which focuses the parallel pencil of rays to form a beam spot on a data-recording disc 3 and which receives the light beam reflected by the disc 3, a beam splitter 5 for redirecting the reflected light beam incident to the objective lens, an optical system 6 comprising a convergent lens 6a and a cylindrical lens 6b to make the redirected light beam an astigmatic pencil of rays and form a beam spot, and a quadrant-division optical detector 7 containing four optical sensor blocks 7a, 7b, 7c and 7d divided by two crossing boundaries each at 45 degree to the generating line of the cylindrical lens 6b, the quadrant-division detector 7 sensing the beam spot formed thereon, thereby detecting the focusing error of the beam spot on the data-recording disc 3 according to the configuration of the beam spot on the quadrant-division optical detector 7.

The data-recording disc 3 comprises a substrate 3a made of such a light-transmitting material as glass, concentric or spiral grooves formed on the substrate 3a to define data tracks 3b and guide tracks 3c, and a data-recording medium 3d comprising a thin film of rare earth-transition metal amorphous alloy deposited over the substrate 3a by evaporation or sputtering, thereby permitting high density recording and reproduction of data.

Detection of focusing error of a beam spot formed on the data recording disc 3 is based on the principle as set forth below. Assuming the light quantities received by the four optical sensor blocks 7a through 7d of the quadrant-division optical detector 7 are Sa, Sb, Sc and Sd, respectively, the degree of focalization "f" of a beam spot formed on the data-recording disc 3 is calculated by the expression: (Sa + Sc) - (Sb + Sd).

Since the beam spot 12 focused properly on the quadrant-division optical detector 7 is round as shown in Figs. 6(a) and 6(b), the light quantities Sa, Sb, Sc and Sd are equal. Accordingly, the degree of focalization "f" calculated by the expression:(Sa + Sc) - (Sb + Sd) is 0 (zero).

When the objective lens 4 is too close to the disc 3 as shown in Fig. 6(c), the beam spot 12 projected on the quadrant-divi sion optical ditector 7 is a ellipse with its major axis oriented in the direction bo in parallel to the generating line of the cylindrical lens 6b, as shown in Fig. 6(d). In such a case, the degreee of focalization "f" is a negative value.

When the objective lens 4 is too remote from the data-recording disc 3 as illustrated in Fig. 6(e), on the other hand, the beam spot 12 on the quadrant-division optical detector 7 is a ellipse with its major axis oriented in the direction a_o at right angle with the generating line of the cylindrical lens 9 as shown in Fig. 6(f). In such a case, the degree of focalization "f" is a positive value.

If the degree of focalization "f" calculated by the expression (Sa + Sc) - (Sb + Sd) is used as a focusing error signal, it is possible to determine on the basis of the value of the focusing error signal that the distance between the data-recording disc 3 and the objective lens 4 is proper, too short or too long.

Meanwhile, the beam spot 12 formed on the quadrant-division optical detector 7 contains a shadow 13 attributable to the diffraction by the guide tracks 3c (the shadow hereinafter referred to as a diffraction pattern). Even when the beam spot 12 is properly focused on the quadrant-division optical detector 7 as shown in Figs. 6(a) and 6(b), the diffraction pattern 13 may vary as illustrated in Figs. 7(b), 7(d) and 7(f) depending upon the position of the beam spot 11 in relation to the data tracks 3b on the data-recording disc 3 as shown in Figs. 7(a), 7(c) and 7(e).

When there is no aberration by the optical system between the light source 1 and the data-recording disc 3, the diffraction pattern 13 is symmetrical with respect to the axis corresponding to the direction at right angle with the guide tracks 3c. Therefor, if the quadrant-division optical detector 7 is positioned in such a manner that the boundary Y-Y dividing the optical sensor blocks 7a and 7b from the optical sensor blocks 7c and 7d coincides with the axis corresponding to the direction at right angle with the guide tracks 3c, the degree of focalization "f" becomes 0,regardless of the diffraction pattern 13 shown in Figs. 7(b), 7(d) and 7(f), as

long as the beam spot 11 is properly focused on the data-recording disc 3. According to the conventional art, however, when there is an aberration in the optical system between the light source 1 and the data-recording disc 3, displacement of the beam spot 11 in relation to the data tracks 3b of the recording disc 3 as shown in Fig. 8(a), 8(c) or 8(e) may impair the symmetry of the diffraction pattern 13 with respect to the axis corresponding to the direction vertical to the guide tracks 3c of the recording disc 3 as shown in Fig. 8(b), 8(d) or 8(f) (the phenomenon called a crosstalk). Consequently, if the beam spot 11 is properly focused, the degree of focalization "f" is positive for the diffraction pattern 13 shown in Fig. 8(b) or negative for the diff raction pattern 13 shown in Fig. 8(f). The degree of focalization "f" is zero only for the diffraction pattern 13 shown in Fig. 8(d).

As a result, even if the objective lens 4 is placed in the range appropriate for focalization, minor variation of the distance between the objective lens 4 and the data-recording disc 3 may cause large fluctuation of the value of the focusing error signal as shown in Fig. 9, which hinders stable focus control.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a focusing error detector with stable focus control without deteriorating the quality of a focusing error signal.

Another object of the present invention is to provide an optical data detecting device incorporating a focusig error detector with stable focus control without deteriorating the quality of a focusing error signal.

Another object of the present invention is to provide an optcal data detecting device provided wih means for preventing the quality of a focusing error signal from being deteriorated by protecting a diffraction pattern attributable to guide tracks, projected on an optical detector, against the influence of the aberration in an optical system.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To overcome the problems of the prior art and to achieve the above objects, according to an embodiment of the present invention, a focusing error detector comprises a light source; a collimator lens for making parallel the light beams emitted from the light source; an objective lens which focuses the parallel light beams to form a beam spot on a data-recording disc with data tracks and guide tracks formed thereon and which receives light beams reflected from the surface of the data-recording disc; an optical system for forming a beam spot from the reflected light beams incident to the objective lens; and an optical detector having a plurality of divided optical sensor blocks for receiving the beam spot thereby detecting the focusing error of the beam spot formed on the data-recording disc according to the configuration of the beam spot on the optical detector. The objective lens and/or the collimator lens are placed at such rotating positions as minimize the influence of aberration in the optical system between the light source and the data-recording disc on the symmetry of a diffraction pattern in the beam spot formed on the optical detector with respect to the axis corresponding to the direction at right angle with the guide tracks.

Alternatively, a parallel plate, which is inclined with respect to the optical axis and rotatable about the optical axis, may be placed either in the divergent or in the convergent zone of the optical path between the light source and the data-recording disc. In that case, the parallel plate is controlled to minimize the influence of the aberration in the optical system between the light source and the data-recording disc.

According to the present invention with such construction as mentioned above, if a diffraction pattern is generated in a beam spot on the optional detector due to diffraction by the guide tracks and if the diffraction pattern varies with displacement of the beam spot on the data-recording disc in relation to the guide tracks, the symmetry of the diffraction pattern with respect to the axis corresponding to the direction vertical to the guide tracks will not be impaired by the influence of the aberration in the optical system between the light source and the data-recording disc. Since the quality of a focusing error signal is not deteriorated, it is possible to detect a focusing error accurately.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention and wherein:

Fig. 1 is an exploded perspective view of the first embodiment of a focusing error detector of the present invention;

Fig. 2 is a longitudinal sectional view of the objective lens unit;

Figs. 3(a) through 3(f) show possible positions of a beam spot in relation to the data tracks and the corresponding diffraction patterns;

Fig. 4 is a graph showing the relationship between the distance from the optical disc to the objective lens and a focusing error signal;

Fig. 5 shows the schematic construction of the conventional focusing error detector;

Figs. 6(a) through 6(f) explain the principle on which the conventional focusing error detector detects a focusing error:

Figs. 7(a) through 7(f) show possible positions of a beam spot in relation to the data tracks and the corresponding diffraction patterns in the conventional focusing error detector;

Figs. 8(a) through 8(f) show possible positions of a beam spot in relation to the data tracks and the corresponding diffraction pattern in the conventional focusing error detector when the collimator lens and the objective lens generate aberration;

Fig. 9 is a graph showing the relationship between the distance from the optical disc to the objective lens and a focusing error signal in the conventional focusing error detector; and

Fig. 10 is an explanatory drawing showing the construction of the second embodiment of a focusing error detector of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The first embodiment of the present invention is described with reference to Figs. 1 through 4.

As shown in Fig. 1, a focusing error detector comprises a semiconductor laser 21 as a light source; a collimator lens unit 22 including a collimator lens 22a for making parallel the pencil of rays emitted by the semiconductor laser 21; an objective lens unit 24 including an objective lens 24a for concentrating the parallel pencil of rays to form a beam spot on an optical disc 23 provided as a data-recording disc and for receiving light beams reflected by the optical disc 23; a beam splitter 25 for redirecting the light beams reflected back through the objective lens 24a; an optical system 26 comprising a convergent lens 26a and a cylindrical lens 26b for making the redirected reflected light beam an astigmatic pencil of rays to form a beam spot; and a quadrant-division optical detector 27 for sensing the beam spot formed by the optical system 26 to detect the focusing error of the beam spot on the optical disc 23 according to the configuration of the sensed beam spot.

The collimator lens unit 22 is rotatably mounted in a recess 28a in a housing 28 and retained by a tension plate 29.

As a data-recording disc, the optical disc 23 comprises a substrate 23a made of such light-transmitting material as glass, concentric or spiral grooves formed on the substrate 23a to define data tracks 23b and guide tracks 23c, the grooves having a depth about one-eighth of the wavelength "λ" of the light emitted by the semiconductor laser 21, a data-recording medium 23d composed of a thin layer of rare earth-transition metal amorphous alloy deposited by evaporation or sputtering over the substrate 23a, thereby permitting high density data recording and reproduction.

The quadrant-division optical detector 27 includes four optican sensor blocks 27a, 27b, 27c and 27d divided by two crossing boundaries X-X and Y-Yd which are at 45 degree to the generating line of the cylindrical lens 26b. The boundary X-X corresponds to the direction parallel to the guide tracks 23c on the optical disc 23, and the boundary Y-Y corresponds to the direction verti cal to the guide tracks 23c.

The objective lens 24a is, as understood from Fig. 2, driven both in the radial direction of the optical disc 23 as indicated by an arrow A (hereinafter referred to as the tracking direction) and in the direction perpendicular to the surface of the optical disc 23 as indicated by an arrow B (hereinafter referred to as the focusing direction). To move the objective lens 24a in the focusing direction, a focusing magnetic circuit comprising a focusing magnet 32, a focusing yoke 33 and a focusing magnetic gap 34 is provided at an end portion of the inner side of a cylindrical stationary support 31. A tracking magnetic circuit comprising a pair of opposed tracking magnets 35,35 is provided in the vicinity of the other end of the stationary support 31.

An intermediate support 38 movably retained by parallel springs 37,... is provided within the stationary support 31. The parallel springs 37,... are lined with elastic rubber materials 36,... and movable in the focusing direction. At an end of the intermediate support 38 is provided a focusing coil 39 inserted in the focusing magnetic gap 34 with a specified space around the focusing coil 39.

An objective lens barrel 42 movable supported by parallel springs 41,41 is mounted within the intermediate suport 38. The parallel springs 41,41 are lined with elastic rubber materials 40,40 and movable in the tracking direction. On the outside wall of the objective lens barrel 42 are mounted tracking coils 43,43 adjacent to the tracking magnets 35,35. At one end of the objective lens barrel 42, an objective lens holder 44 for retaining the

objective lens 24a is mounted rotatably with respect to the objective lens barrel 42. A counter balance weight 45 is provided at the other end of the objective lens barrel 42.

In the focusing error detector of the above construction, a shadow 53 attributable to the diffraction by the guide tracks 23c (hereinafter referred to as a diffraction pattern) is formed in a beam spot 52 projected on the quadrant-division optical detector 27 as shown in Fig. 3(b), 3(d) or 3-(f). The diffraction pattern 53 changes with displacement of the beam spot 51 in relation to the data tracks 23b on the optical disc 23 as illustrated in Figs. 3(b), 3(d) and 3(f). In other words, there is no crosstalk in the diffraction pattern 53.

Here, assuming the light quantities received by the four optical sensor blocks 27a, 27b, 27c and 27d of the quadrant-division optical detector 27 are Sa, Sb, Sc and Sd, respectively, the degree of focalization "f" of the beam spot 51 formed on the optical disc 23 is calculated by the expression: (Sa + Sc) - (Sb + Sd). If the beam spot 51 is properly focused, the degree of focalization "f" is always 0-(zero) independent of the position of the beam spot 51 with respect to the data tracks 23b.

Accordingly, if the distance between the objective lens 24a and the optical disc 23 is close to the focal length, it is possible to detect focusing error accurately on the basis of the degree of focalizaiton "f" which may be positive, zero or negative. This permits stable focusing control.

The positions of the objective lens 24a and collimator lens 22a need not be changed once they have been adjusted. Therefore, after position adjustment, the objective lens 24a may be secured together with the objective lens holder 44 to the objective lens barrel 42, and the collimator lens 22a may be secured together with an colimator lens holder (not shown) to the housing 28 by using adhesives.

In the above first embodiment of the present invention, the rotation position of both objective lens 24a and collimator lens 22a is adjusted, though it is not necessary to adjust both of them. The same advantageous effect as in the above first embodiment is obtained by a modification in which either the objective lens 24a or the collimator lens 22a is adjusted for its rotation position with the other fixed.

The second embodiment of the present invention is described in the following. Fig. 10 shows the construction of the second embodiment of a focusing error detector of the present invention.

Referring to Fig. 10, a glass parallel plate 71 is disposed between the collimator lens 22 and the semiconductor laser 21. The parallel plate 71 is rotatable about the optical axis 72. Assuming that the parallel plate 71 has a thickness of "t" and a refractive index of "n" and is inclined at the angle θ with the optical axis in the light beam of the divergent angle α, the parallel plate 71 generates an astigmatism expressed by:

$$w = \frac{t}{2} \frac{(n^2-1)\sin^2\theta}{(n^2-\sin^2\theta)^{3/2}} \sin^2\alpha .$$

In the second embodiment, the astigmatism effected by the parallel plate 71 is used to eliminate the astigmatism of the orientation neither parallel nor vertical to the data tracks 23c which astigmatism may remain in the optical system between the light source 21 and the optical disc 23, thereby obtaining a focusing error signal of good quality. Namely, the orientation of astigmatism is controllable by rotating the parallel plate 71 about the optical axis, and the extent of astigmatism either by changing the inclination angle θ of the parallel plate 71 or by varying the thickness "t" and refractive index "n" of the parallel plate 71. To obtain a diffraction pattern symmetrical with respect to the axis corresponding to the direction at right angle with the guide tracks 23c of the optical disc 23 as shown in Fig. 3(b), 3(d) or 3(f), therefore, the parallel plate 71 of the appropriate thickness and of appropriate refractive index is set at an appropriate angle to the optical axis so as to offset the astigmatism originating in the optical system between the light source 21 and the optical disc 23. Thus, according to the present invention, no crosstalk occurs in the diffraction pattern so that stable focus control is attained.

In the above second embodiment of the present invention, the parallel plate 71 is place in the divergent zone of the laser beam. The same advantageous effect as in the second embodiment is obtained by placing the parallel plate 71 in the convergent zone of the laser beam.

According to the present invention, as understood from the above, aberration in the optical system between the light source and the optical disc is eliminated. Therefore, the symmetry with respect to the axis corresponding to the direction vertical to the guide tracks, of the diffraction pattern in the beam spot formed on the optical detector can never be impaired by aberration of the optical system. As a result, the focusing error detector of the present invention provides stable focus control without deteriorating the quality of a focusing error signal.

The focusing error detector of the present invention is used in an optical data detecting device which records and reproduces data on a data-recording disc such as an optical disc or an optical magnetic disc with concentric or spiral data tracks and guide tracks formed thereon.

While only certain embodiments of the present invention have been described, it wil be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit and scope of the present invention as claimed.

There are described above novel features which the skilled man will appreciate give rise to advantages. These are each independent aspects of the invention to be covered by the present application, irrespective of whether or not they are included within the scope of the following claims.

Claims

1. A focusing error detector, comprising: a light source; a collimator lens for making parallel the pencil of rays emitted by said light source; an objective lens which focuses the parallel pencil of rays to form a beam spot on a data-recording disc with data tracks and guide tracks formed thereon and which receives the pencil of rays reflected from said data-recording disc; an optical system for forming a beam spot from the reflected pencil of rays incident to said objective lens; and an optical detector having a plurality of divided optical sensor blocks for receiving the beam spot formed on said optical detector, said optical detector detecting the focusing error of the beam spot formed on said data-recording disc on the basis of the configuration of the received beam spot, wherein said objective lens and/or said collimator lens are place at such rotation positions as minimize the influence of aberration in the optical system between the light source and the data-recording disc on the symmetry with respect to the axis corresponding to the direction at right angle with the guide tracks, of a diffraction pattern formed in said beam spot on the optical detector.

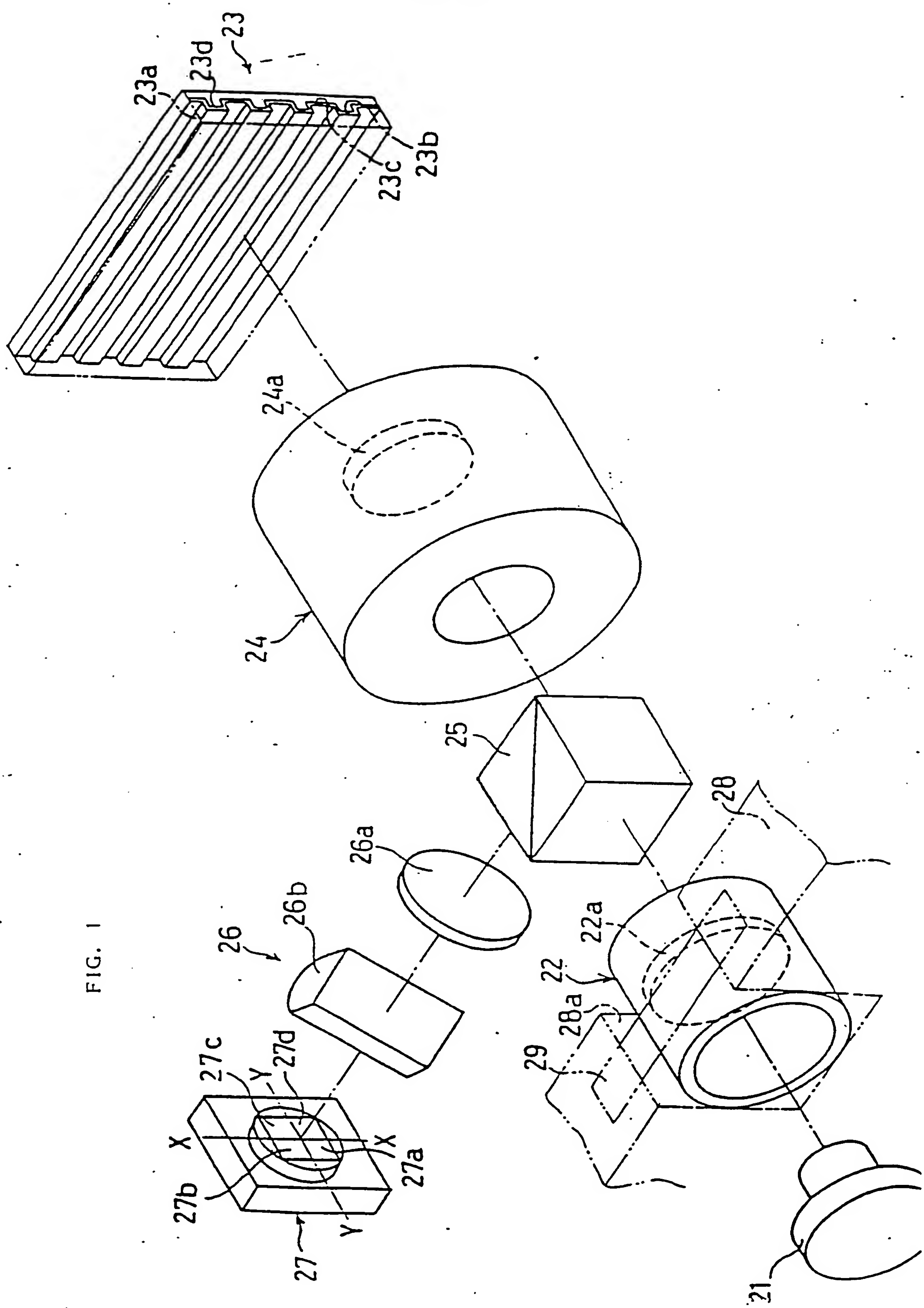
2. A focusing error detector, wherein a parallel plate inclined with respect to the optical axis and rotatable about the op tical axis is placed in either the optical divergent or the convergent zone in the optical path between a light source and a data-recording disc, said parallel plate being controlled so as to minimize the influence of aberration in the optical system between the light source and the data-recording disc.

3. An optical data detecting device, comprising: a light source; an objective lens for concentrating the pencil of rays emitted from said light source onto a data-recording disc with circular or spiral guide tracks formed thereon and for receiving the pencil of rays reflected from said data-recording disc; and an optical system for transmitting said reflected pencil of rays into an optical detector having a plurality of divided optical sensor blocks, wherein said objective lens is positioned in such orientation as to minimize the inverse affect of the aberration by said objective lens on a diffractive pattern projected on said optical detector.

4. The focusing error detector of claim 1, wherein said focusing error detector is mounted in an optical data detecting device.

5. The focusing error detector of claim 2, wherein said focusing error detector is mounted in an optical data detecting device.

6. Apparatus for recording, reproducing and/or erasing information on an optical recording medium (23) using a beam of radiation which is focussed by a beam focussing means (22, 24) into a light spot on said medium, the apparatus having means (27) for determining the focus condition of said light spot, said determining means including an optical detector (27) which has a light sensor area divided into a plurality of area portions (27a-d), and being operable to determine said focus condition in accordance with the distribution between said sensor area portions of an image of said light spot projected onto said light sensor area, wherein means (42, 44, 28a, 29, 71) is provided for compensating for the effect which aberration in the optical system (22, 24) between the source of the radiation and the medium tends to have upon the symmetry of a diffraction pattern formed on the light sensor area due guide track portions (23c) of the medium (23) in the region of the light spot.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23d
23c
23b
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26a
26b
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27c
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27d
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27a
27b
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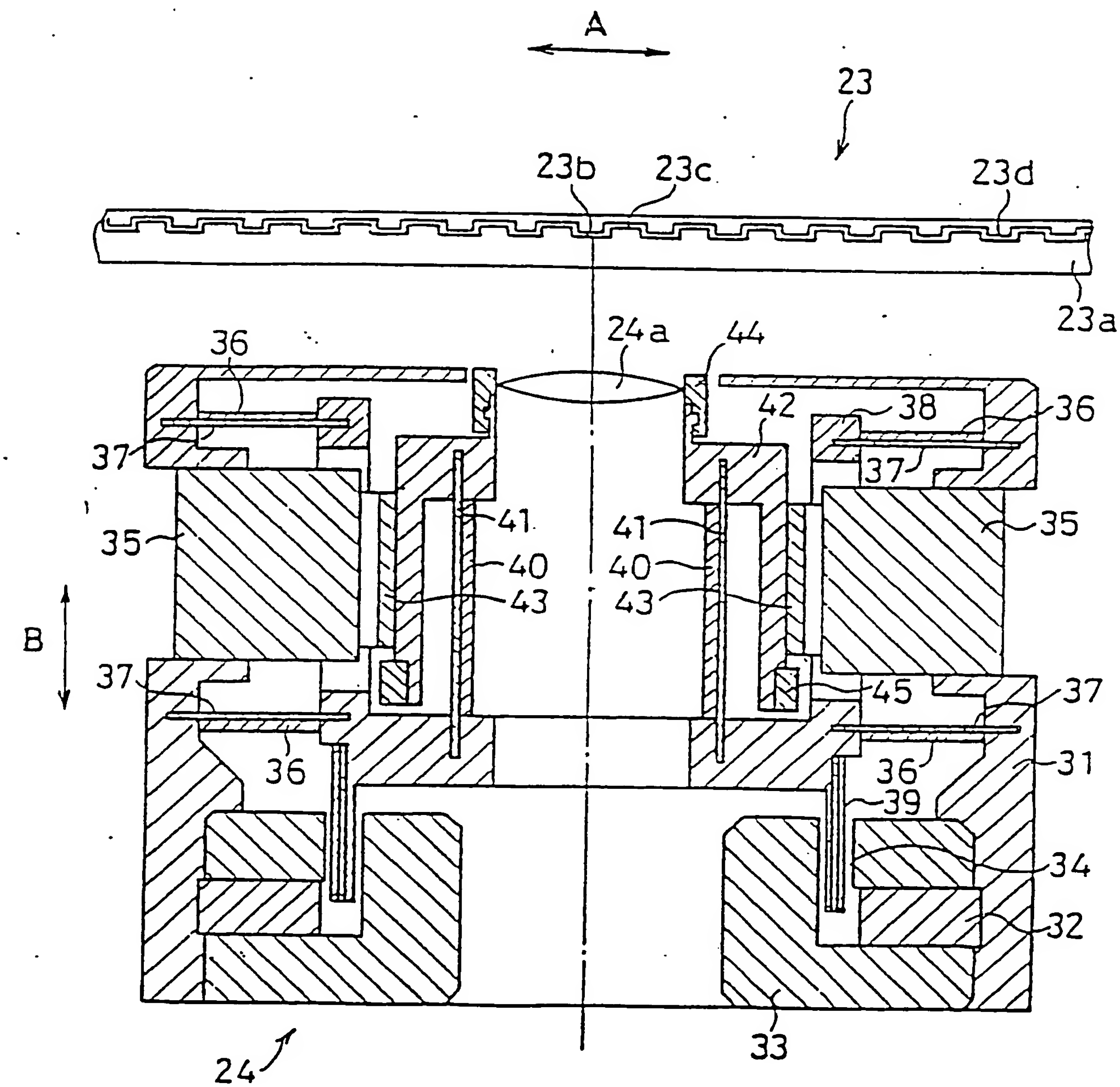
FIG. 1

FIG. 2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23b
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FIG. 3(a)

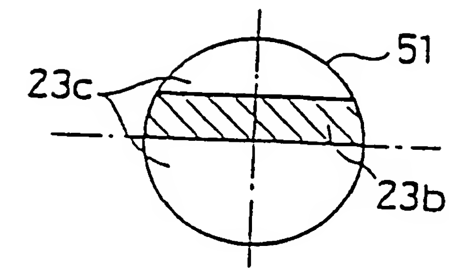


FIG. 3(b)

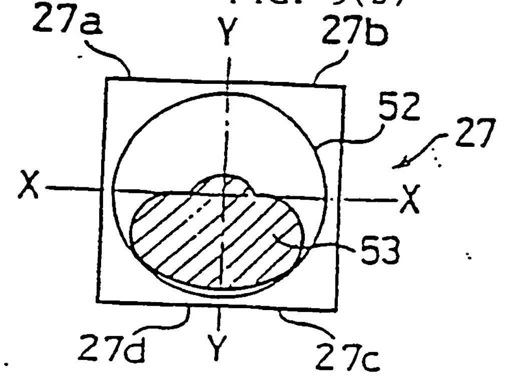


FIG. 3(c)

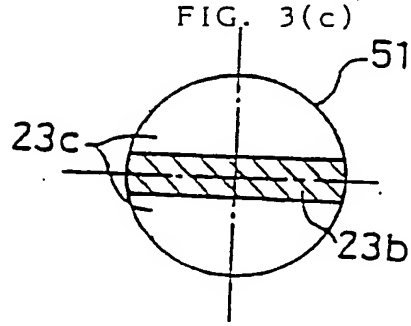


FIG. 3(d)

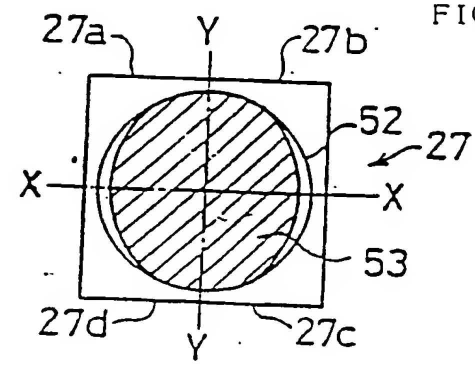


FIG. 3(e)

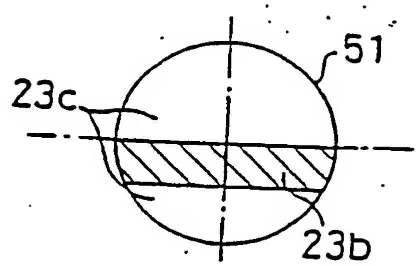


FIG. 3(f)

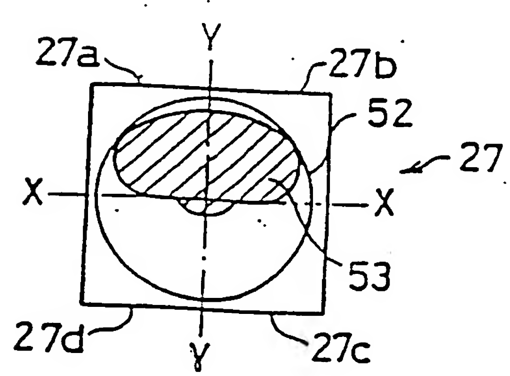


FIG. 4

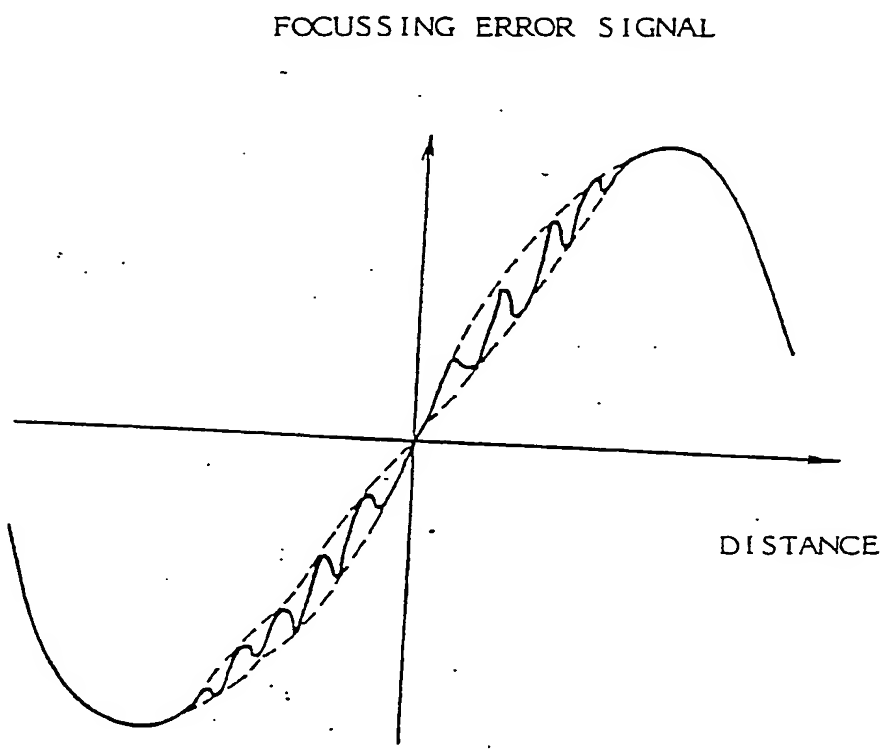


FIG. 5

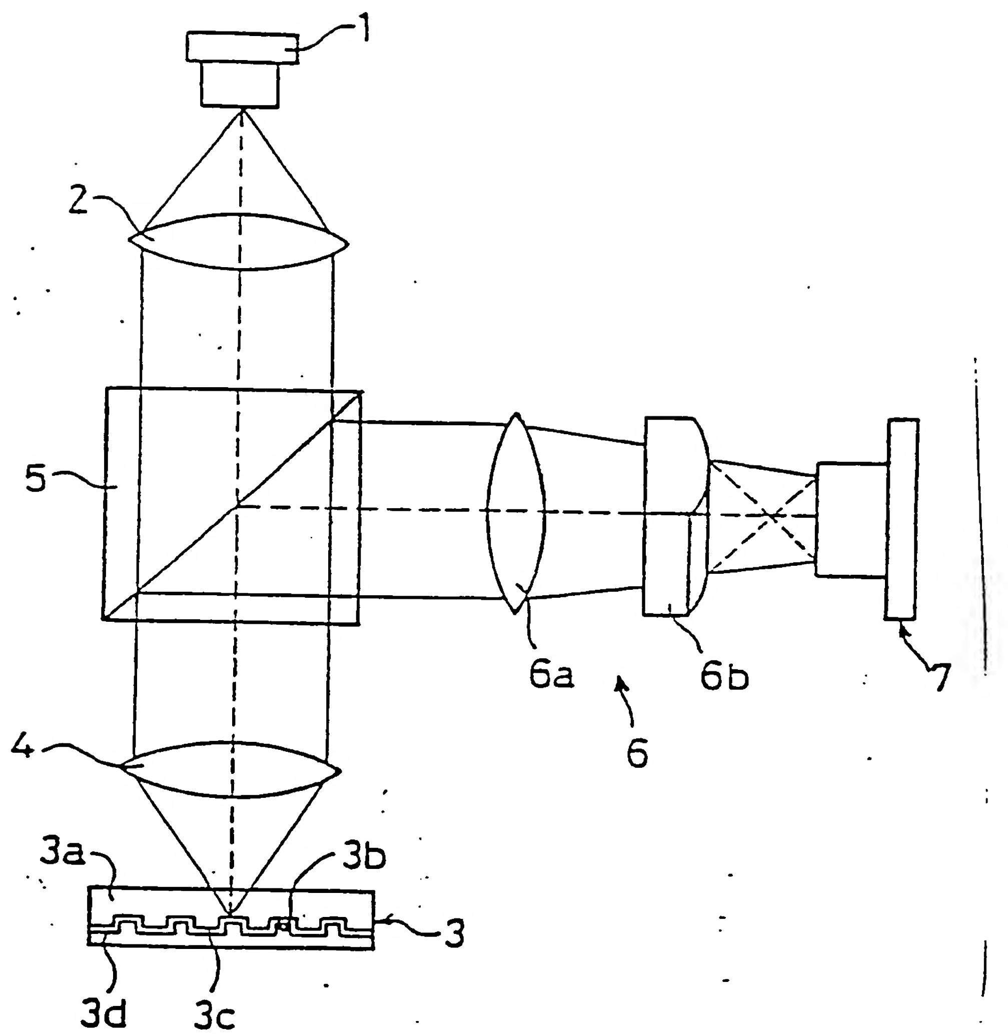


FIG. 6(a)

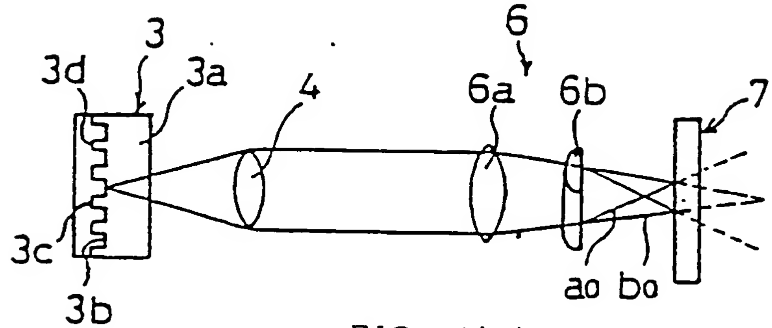


FIG. 6(b)

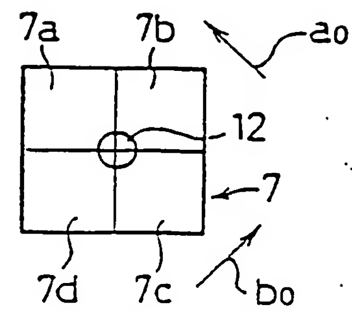


FIG. 6(c)

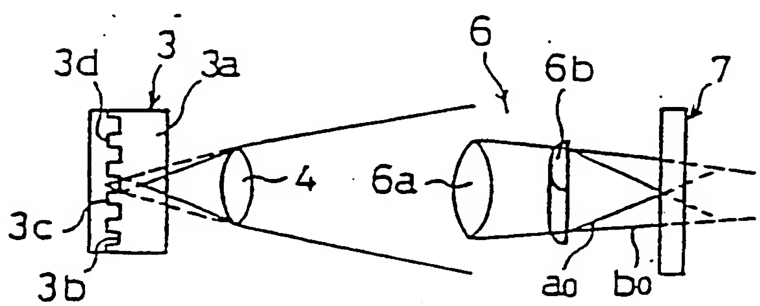


FIG. 6(d)

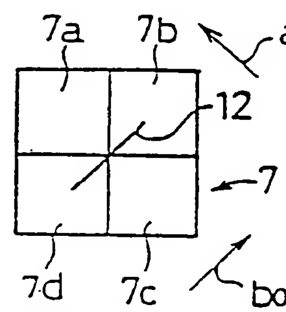


FIG. 6(e)

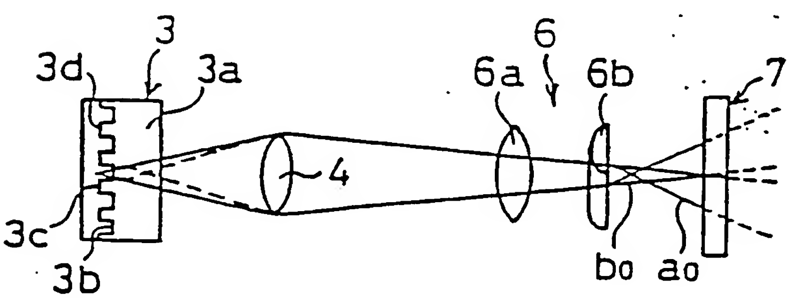


FIG. 6(f)

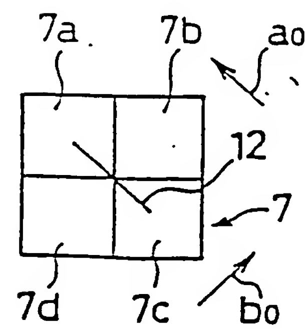


FIG. 7(a)

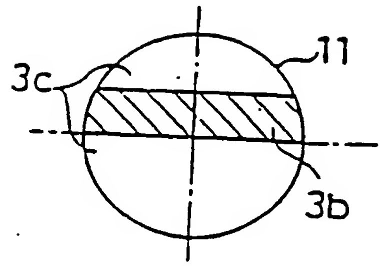


FIG. 7(b)

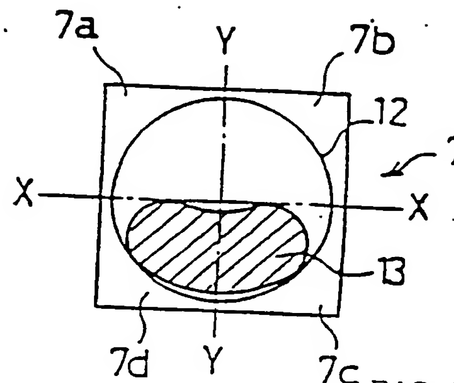


FIG. 7(c)

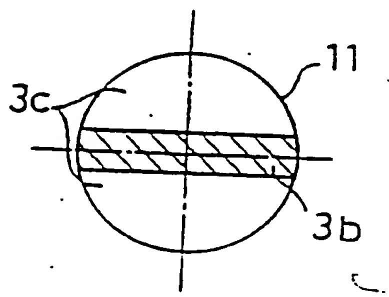


FIG. 7(d)

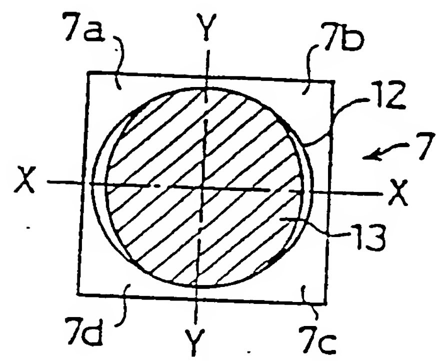


FIG. 7(e)

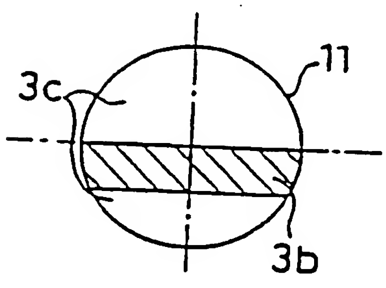


FIG. 7(f)

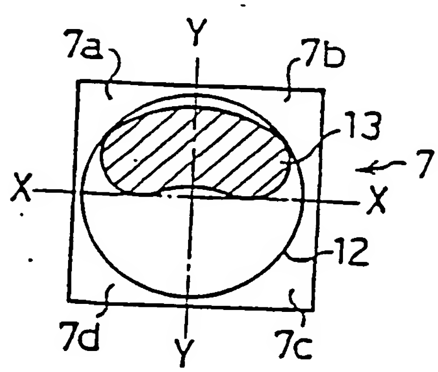


FIG. 8(a)

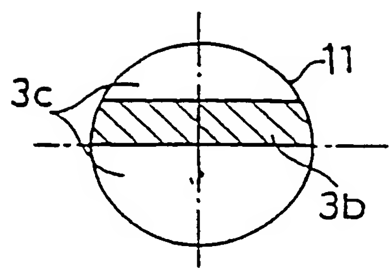


FIG. 8(b)

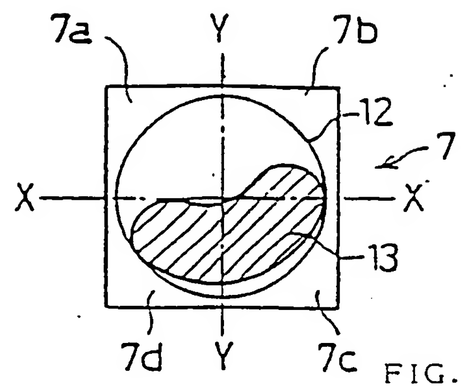


FIG. 8(c)

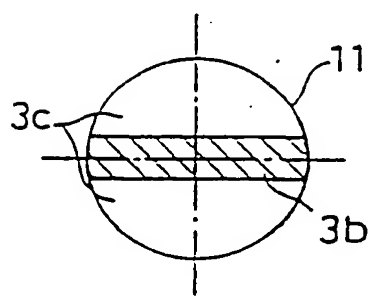


FIG. 8(d)

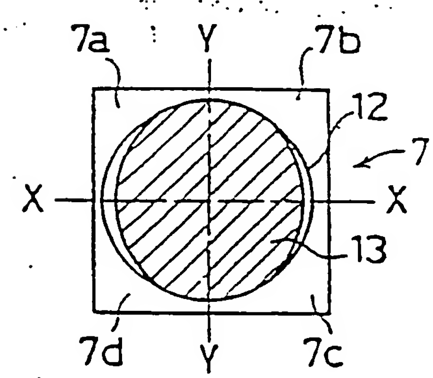


FIG.8(e)

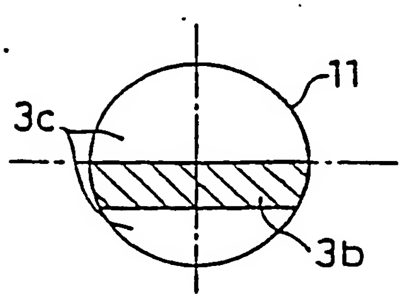


FIG. 8(f)

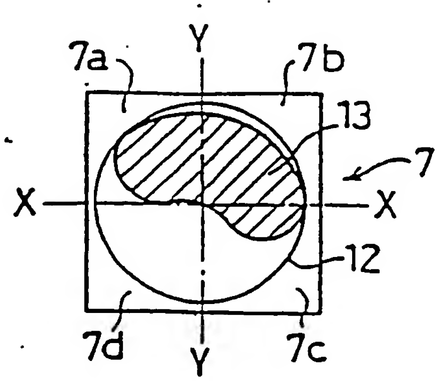
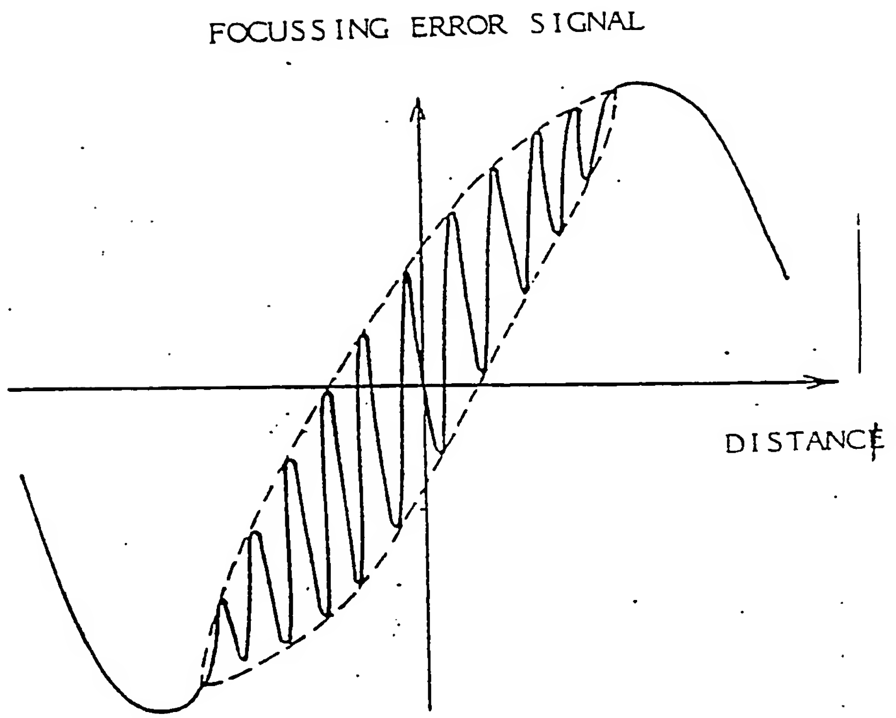


FIG. 9



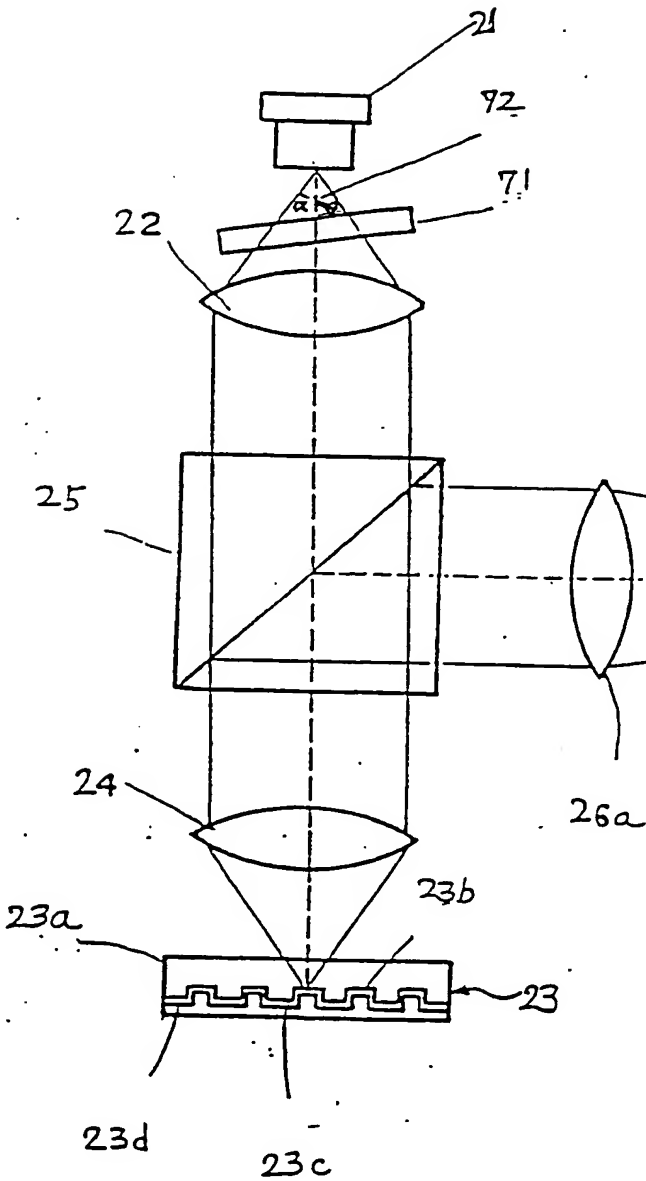


FIG. 10